Arctic Mixed-Phase Cloud Dissipation and its Relationship to Low CCN Concentrations

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Overview

Main Question: Can a lack of environmental CCN/aerosol be a primary factor for Arctic cloud dissipation?

- Persistent mixed-phase boundary layer clouds are important regulators for Arctic (and global) climate.
- Accurately modeling Arctic clouds are important to properly simulate the global climate system.
- Unlike in lower latitudes, Arctic aerosol concentrations have been hypothesized to be low enough to inhibit cloud formation
  - Mauritsen et al. (2011) coined the term "tenuous clouds" in which cloud structure was limited by aerosol concentration

Simulation Setup

Regional Atmospheric Modeling System (RAMS) in LES mode

- Harrington 2-stream radiation
- RAMS 2M bulk microphysics
- Prescribed aerosol concentration
- dx, dy = 62.5 m
- dz = 6.25 m
- Domain = 6 x 6 x 1.25 km

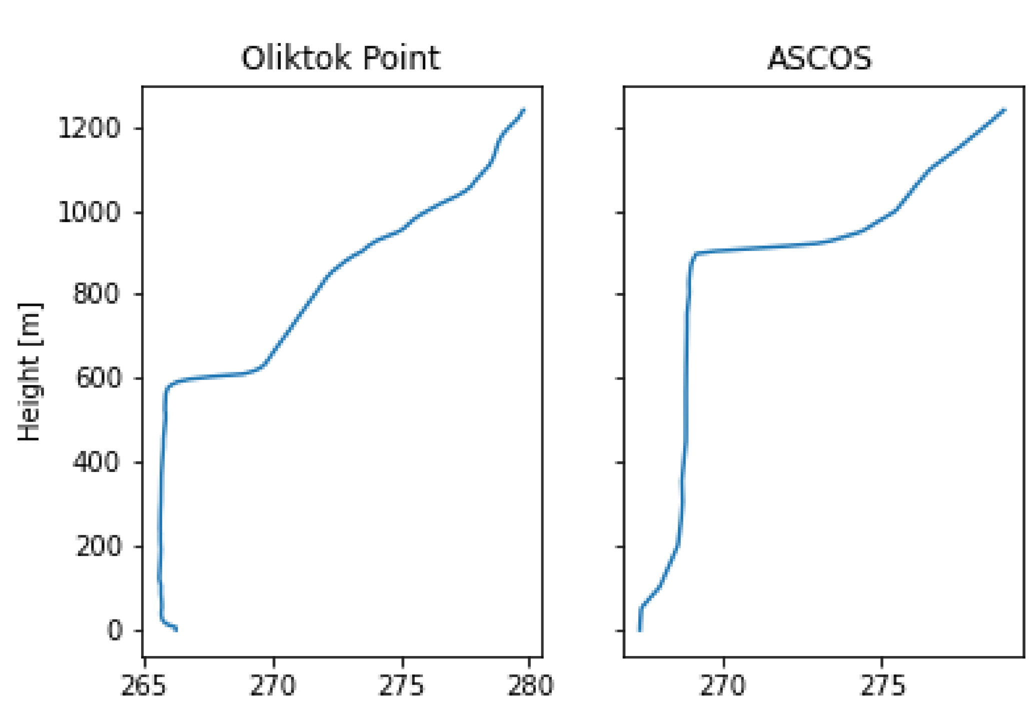

Figure 1: Boundary layer θ profiles used to initialize LES simulations

Cases

Two potential cases have been identified where cloud dissipation occurred coincidentally with a surface aerosol concentration decrease:

- Oliktok Point - May 12th, 2017 - Northern slope of Alaska - ocean/land boundary
- ASCOS - August 31st, 2008 - Arctic ocean ice floe

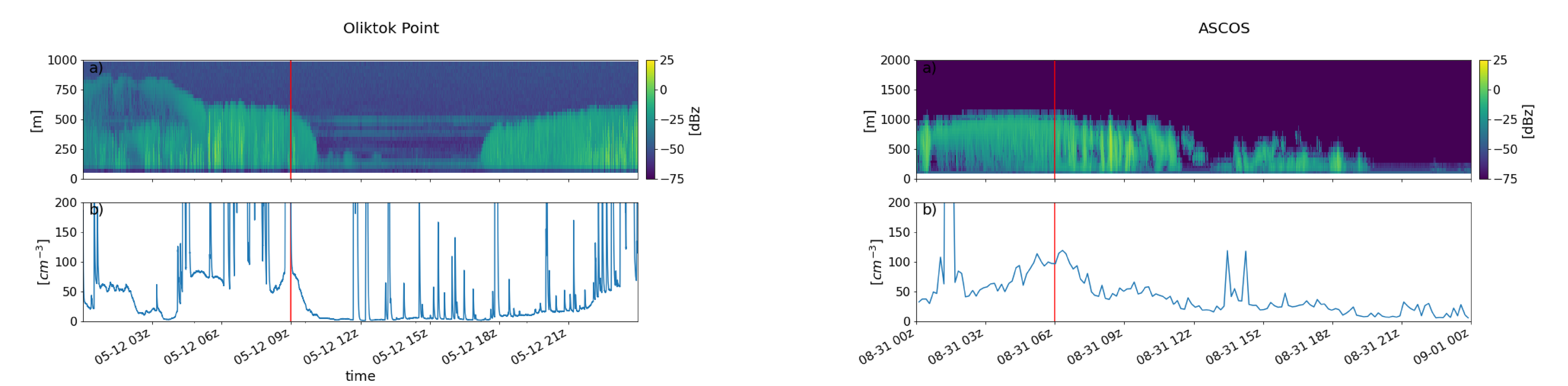

Figure 2: Observed Ka-band radar reflectivity (top) and CPC aerosol concentration (bottom) for Oliktok Point and ASCOS

Simulation Results

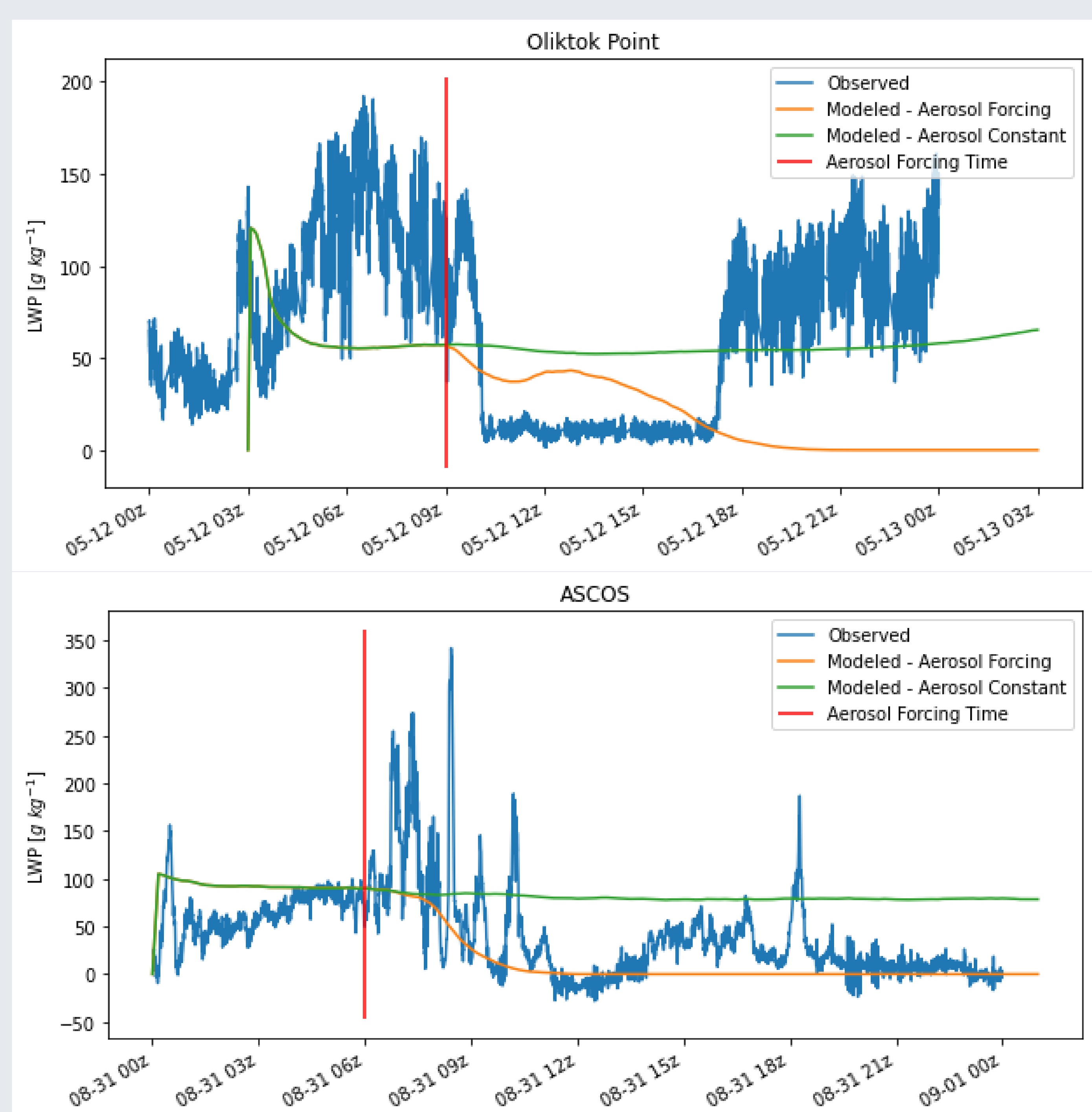

Figure 3: Observed and simulated liquid water path (LWP) for Oliktok Point (top) and ASCOS (bottom).

Balloon soundings and observed aerosol concentrations used to initialize LES model

Two simulations per case:

- Stable-cloud control
  - Aerosol concentration held constant throughout, no source/sink
- Aerosol Forcing Experiment
  - Same as control, but aerosol forced to 0 cm^{-3} at the time denoted by the red line

Compare LWP response to aerosol forcing against observed LWP at time of cloud dissipation.

- Oliktok Point simulated LWP response was much slower than observed
- ASCOS simulated LWP response was similar to observed

Discussion

The extreme forcing simulations were done to ascertain whether or not aerosol-limited dissipation could be the cause of the observed dissipation cases. Ideally, these extreme aerosol forcings should

- If the modeled LWP response was slower than the observed, then other effects must be enhancing the dissipation rate
- If modeled LWP response was faster than observed, limited aerosol may be the primary cause of dissipation, but is not possible to say for certain

Main Takeaways

- The Oliktok Point simulated LWP response was much slower than observed, indicating that other factors were likely forcing the cloud disspiation
- The ASCOS simulated LWP response matched closely with the observed decay, suggesting that the ASCOS case may have dissipated due to lack of aerosol

Conclusions

- It is difficult to isolate the role of aerosol concentration on observed cloud dissipation
- When doing an "extreme" level of aerosol forcing, the ASCOS simulation agreed much closer to observations than Oliktok Point.
  - ASCOS dissipation may be forced by aerosol concentrations, but impossible to say for sure

Future Work

- Simulate various (and more realistic) aerosol treatment methods
- Examine in-cloud processes
- Locate and test more cases

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